



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : C12N 15/62, 15/31, 15/54, 1/21, A61K 38/45		A2	(11) International Publication Number: WO 95/04151 (43) International Publication Date: 9 February 1995 (09.02.95)
(21) International Application Number: PCT/GB94/01647 (22) International Filing Date: 29 July 1994 (29.07.94) (30) Priority Data: PCT/GB93/01617 30 July 1993 (30.07.93) WO (34) Countries for which the regional or international application was filed: GB et al. 9401787.8 31 January 1994 (31.01.94) GB (71) Applicant (for all designated States except US): MEDEVA HOLDINGS B.V. [NL/NL]; Churchill-Laan 223, NL-1078 ED Amsterdam (NL). (72) Inventors; and (75) Inventors/Applicants (for US only): KHAN, Mohammed, Anjam [GB/GB]; Cambridge University Dept. of Pathology, Tennis Court Road, Cambridge CB2 1QP (GB). HOR-MAECHE, Carlos, Estenio [GB/GB]; Cambridge University Dept. of Pathology, Tennis Court Road, Cambridge CB2 1QP (GB). CHATFIELD, Steven, Neville [GB/GB]; Medeva Vaccine Research Unit, Dept. of Biochemistry, Imperial College of Science and Technology, London SW7 2AY (GB). DOUGAN, Gordon [GB/GB]; Medeva Vaccine Research Unit, Dept. of Biochemistry, Imperial College of Science and Technology, London SW7 2AY (GB).			(74) Agents: HUTCHINS, Michael, Richard et al.; Fry Heath & Spence, St. Georges House, 6 Yattendon Road, Horley, Surrey RH6 7BS (GB). (81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, ES, FI, GB, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LT, LU, LV, MD, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD). Published <i>Without international search report and to be republished upon receipt of that report.</i>

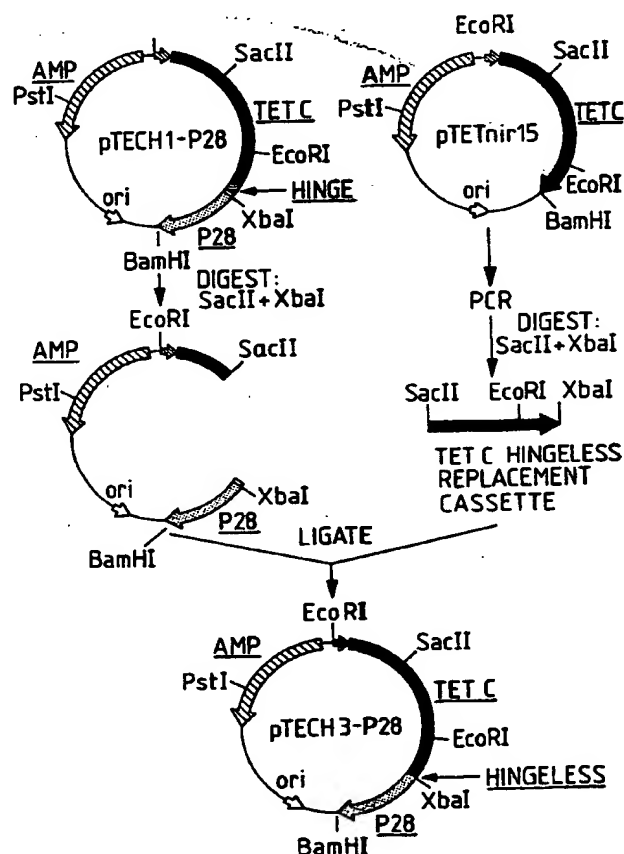
Published

Without international search report and to be republished upon receipt of that report.

(54) Title: **VACCINE COMPOSITIONS**

(57) Abstract

The invention provides a DNA construct comprising a DNA sequence encoding a fusion protein of the formula: TetC-(Z)_a-Het, wherein: TetC is the C fragment of tetanus toxin, or a protein comprising the epitopes thereof; Het is a heterologous protein, Z is an amino acid, and _a is zero or a positive integer, provided that (Z)_a does not include the sequence Gly-Pro. The invention also provides replicable expression vectors containing the constructs, bacteria transformed with the constructs, the fusion proteins *per se* and vaccine compositions formed from the fusion proteins or attenuated bacteria expressing the fusion proteins.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GB	United Kingdom	MR	Mauritania
AU	Australia	GE	Georgia	MW	Malawi
BB	Barbados	GN	Guinea	NE	Niger
BE	Belgium	GR	Greece	NL	Netherlands
BF	Burkina Faso	HU	Hungary	NO	Norway
BG	Bulgaria	IE	Ireland	NZ	New Zealand
BJ	Benin	IT	Italy	PL	Poland
BR	Brazil	JP	Japan	PT	Portugal
BY	Belarus	KE	Kenya	RO	Romania
CA	Canada	KG	Kyrgyzstan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo	KR	Republic of Korea	SE	Sweden
CH	Switzerland	KZ	Kazakhstan	SI	Slovenia
CI	Côte d'Ivoire	LI	Liechtenstein	SK	Slovakia
CM	Cameroon	LK	Sri Lanka	SN	Senegal
CN	China	LU	Luxembourg	TD	Chad
CS	Czechoslovakia	LV	Latvia	TG	Togo
CZ	Czech Republic	MC	Monaco	TJ	Tajikistan
DE	Germany	MD	Republic of Moldova	TT	Trinidad and Tobago
DK	Denmark	MG	Madagascar	UA	Ukraine
ES	Spain	ML	Mali	US	United States of America
FI	Finland	MN	Mongolia	UZ	Uzbekistan
FR	France			VN	Viet Nam
GA	Gabon				

VACCINE COMPOSITIONS

This invention relates to DNA constructs, replicable expression vectors containing the constructs, bacteria containing the constructs and vaccines containing the bacteria or fusion proteins expressed therefrom. More particularly, the invention relates to novel DNA constructs encoding the C-fragment of tetanus toxin, and to fusion proteins containing tetanus toxin C-fragment.

It is known to prepare DNA constructs encoding two or more heterologous proteins with a view to expressing the proteins in a suitable host as a single fusion protein. However, it has often been found that fusing two proteins together in this way leads to an incorrectly folded chimaeric protein which no longer retains the properties of the individual components. For example, the B-subunits of the Vibrio cholerae (CT-B) and E. coli (LT-B) enterotoxins are powerful mucosal immunogens but genetic fusions to these subunits can alter the structure and properties of the carriers and hence their immunogenicity (see M. Sandkvist et al. J. Bacteriol. 169, pp4570-6, 1987, Clements et al. 1990 and M. Lipscombe et al. Mol. Microbiol. 5, pp 1385, 1990). Moreover, many heterologous proteins expressed in bacteria are not produced in soluble

properly folded or active forms and tend to accumulate as insoluble aggregates (see C. Schein et al. Bio/Technology 6, pp 291-4, 1988 and R. Halenbeck et al. Bio/Technology 7, pp 710-5, 1989).

In our earlier unpublished international patent application PCT/GB93/01617, it is disclosed that by providing a DNA sequence encoding tetanus toxin C-fragment (TetC) linked via a "hinge region" to a second sequence encoding an antigen, the expression of the sequence in bacterial cells is enhanced relative to constructs wherein the C-fragment is absent. For example, the expression level of the full length P28 glutathione S-transferase protein of S. mansoni when expressed as a fusion to TetC from the nirB promoter was greater than when the P28 protein was expressed alone from the nirB promoter. The TetC fusion to the full length P28 protein of S. mansoni was soluble and expressed in both E. coli and S. typhimurium. In addition, the TetC-P28 fusion protein was capable of being affinity purified by a glutathione agarose matrix, suggesting that the P28 had folded correctly to adopt a conformation still capable of binding to its natural substrate. It was previously considered that a hinge region, which typically is a sequence encoding a high proportion of proline and/or glycine amino acids, is essential for promoting the independent folding of both the TetC and the antigenic protein fused thereto. However, it has now been discovered, surprisingly in view of the previous studies on CT-B and LT-B referred to above, that

3.

when the hinge region is omitted between the TetC and a second antigen such as P28, the proteins making up the fusion do exhibit correct folding as evidenced by affinity purification on a glutathione agarose matrix.

Accordingly, in a first aspect, the invention provides a DNA construct comprising a DNA sequence encoding a fusion protein of the formula TetC-(Z)_a-Het, wherein TetC is the C fragment of tetanus toxin, or a protein comprising the epitopes thereof; Het is a heterologous protein; Z is an amino acid, and a is zero or a positive integer, provided that (Z)_a does not include the sequence Gly-Pro.

Typically (Z)_a is a chain of 0 to 15 amino acids, for example 0 to 10, preferably less than 6 and more preferably less than 4 amino acids.

In one embodiment (Z)_a is a chain of two or three amino acids, the DNA sequence for which defines a restriction endonuclease cleavage site.

In another embodiment, a is zero.

Usually the group (Z)_a will not contain, simultaneously, both glycine and proline, and generally will not contain either glycine or proline at all.

In a further embodiment, (Z)_a is a chain of amino acids provided that when a is 6 or more, (Z)_a does not contain glycine or proline.

The group (Z)_a may be a chain of amino acids substantially devoid of biological activity.

In a second aspect the invention provides a replicable expression vector, for example suitable for us in

bacteria, containing a DNA construct as hereinbefore defined.

In another aspect, the invention provides a host (e.g. a bacterium) containing a DNA construct as hereinbefore defined, the DNA construct being present in the host either in the form of a replicable expression vector such as a plasmid, or being present as part of the host chromosome, or both.

In a further aspect, the invention provides a fusion protein of the form TetC-(Z)₃-Het as hereinbefore defined, preferably in substantially pure form, said fusion protein being expressible by a replicable expression vector as hereinbefore defined.

In a further aspect the invention provides a process for the preparation of a bacterium (preferably an attenuated bacterium) which process comprises transforming a bacterium (e.g. an attenuated bacterium) with a DNA construct as hereinbefore defined.

The invention also provides a vaccine composition comprising an attenuated bacterium, or a fusion protein, as hereinbefore defined, and a pharmaceutically acceptable carrier.

The heterologous protein "Het" may for example be a heterologous antigenic sequence, e.g. an antigenic sequence derived from a virus, bacterium, fungus, yeast or parasite.

Examples of viral antigenic sequences are sequences derived from a type of human immunodeficiency virus (HIV) such as HIV-1 or HIV-2, the CD4 receptor binding site from

HIV, for example from HIV-1 or -2., hepatitis A, B or C virus, human rhinovirus such as type 2 or type 14, Herpes simplex virus, poliovirus type 2 or 3, foot-and-mouth disease virus (FMDV), rabies virus, rotavirus, influenza virus, coxsackie virus, human papilloma virus (HPV), for example the type 16 papilloma virus, the E7 protein thereof, and fragments containing the E7 protein or its epitopes; and simian immunodeficiency virus (SIV).

Examples of antigens derived from bacteria are those derived from Bordetella pertussis (e.g. P69 protein and filamentous haemagglutinin (FHA) antigens), Vibrio cholerae, Bacillus anthracis, and E.coli antigens such as E.coli heat Labile toxin B subunit (LT-B), E.coli K88 antigens, and enterotoxigenic E.coli antigens. Other examples of antigens include the cell surface antigen CD4, Schistosoma mansoni P28 glutathione S-transferase antigens (P28 antigens) and antigens of flukes, mycoplasma, roundworms, tapeworms, Chlamydia trachomatis, and malaria parasites, eg. parasites of the genus plasmodium or babesia, for example Plasmodium falciparum, and peptides encoding immunogenic epitopes from the aforementioned antigens.

Particular antigens include the full length Schistosoma mansoni P28, and oligomers (e.g. 2, 4 and 8-mers) of the immunogenic P28 aa 115-131 peptide (which contains both a B and T cell epitope), and human papilloma virus E7 protein, Herpes simplex antigens, foot and mouth disease virus antigens and simian immunodeficiency virus

antigens.

The DNA constructs of the present invention may contain a promoter whose activity is induced in response to a change in the surrounding environment. An example of such a promoter sequence is one which has activity which is induced by anaerobic conditions. A particular example of such a promoter sequence is the nirB promoter which has been described, for example in International Patent Application PCT/GB92/00387. The nirB promoter has been isolated from E.coli, where it directs expression of an operon which includes the nitrite reductase gene nirB (Jayaraman et al, J. Mol. Biol. 196, 781-788, 1987), and nirD, nirC, cysG (Peakman et al, Eur. J. Biochem. 191, 315323, 1990). It is regulated both by nitrite and by changes in the oxygen tension of the environment, becoming active when deprived of oxygen, (Cole, Biochem, Biophys. Acta. 162, 356-368, 1968). Response to anaerobiosis is mediated through the protein FNR, acting as a transcriptional activator, in a mechanism common to many anaerobic respiratory genes. By deletion and mutational analysis the part of the promoter which responds solely to anaerobiosis has been isolated and by comparison with other anaerobically regulated promoters a consensus FNR-binding site has been identified (Bell et al, Nucl, Acids. Res. 17, 3865-3874, 1989; Jayaraman et al, Nucl, Acids, Res. 17, 135-145, 1989). It has also been shown that the distance between the putative FNR-binding site and the -10 homology region is critical (Bell et al, Molec. Microbiol. 4, 1753-

1763, 1990). It is therefore preferred to use only that part of the nirB promoter which responds solely to anaerobiosis. As used herein, references to the nirB promoter refer to the promoter itself or a part or derivative thereof which is capable of promoting expression of a coding sequence under anaerobic conditions. The preferred sequence, and which contains the nirB promoter is:

AATTCAGGTAAATTTGATGTACATCAAATGGTACCCCTTGCTGAATCGTTAAGG
TAGGCGGTAGGGCC (SEQ ID NO: 1)

In a most preferred aspect, the present invention provides a DNA molecule comprising the nirB promoter operably linked to a DNA sequence encoding a fusion protein as hereinbefore defined.

In another preferred aspect of the invention, there is provided a replicable expression vector, suitable for use in bacteria, containing the nirB promoter sequence operably linked to a DNA sequence encoding a fusion protein as hereinbefore defined.

The DNA molecule or construct may be integrated into the bacterial chromosome, e.g. by methods known per se, and thus in a further aspect, the invention provides a bacterium having in its chromosome, a DNA sequence or construct as hereinbefore defined.

Stable expression of the fusion protein can be obtained in vivo. The fusion protein can be expressed in an attenuated bacterium which can thus be used as a vaccine.

The attenuated bacterium may be selected from the genera Salmonella, Bordetella, Vibrio, Haemophilus, Neisseria and Yersinia. Alternatively, the attenuated bacterium may be an attenuated strain of enterotoxigenic Escherichia coli. In particular the following species can be mentioned: S.typhi - the cause of human typhoid; S.typhimurium - the cause of salmonellosis in several animal species; S.enteritidis - a cause of food poisoning in humans; S.choleraesuis - a cause of salmonellosis in pigs; Bordetella pertussis - the cause of whooping cough; Haemophilus influenzae - a cause of meningitis; Neisseria gonorrhoea the cause of gonorrhoea; and Yersinia - a cause of food poisoning.

Examples of attenuated bacteria are disclosed in, for example EP-A-0322237 and EP-A-0400958, the disclosures in which are incorporated by reference herein.

An attenuated bacterium containing a DNA construct according to the invention, either present in the bacterial chromosome, or in plasmid form, or both, can be used as a vaccine. Fusion proteins (preferably in substantially pure form) expressed by the bacteria can also be used in the preparation of vaccines. For example, a purified TetC-P28 fusion protein in which the TetC protein is linked via its C-terminus to the P28 protein with no intervening hinge region has been found to be immunogenic on its own. In a further aspect therefore, the invention provides a vaccine composition comprising a pharmaceutically acceptable carrier or diluent and, as active ingredient, an attenuated

bacterium or fusion protein as hereinbefore defined.

The vaccine may comprise one or more suitable adjuvants.

The vaccine is advantageously presented in a lyophilised form, for example in a capsular form, for oral administration to a patient. Such capsules may be provided with an enteric coating comprising, for example, Eudragit "S", Eudragit "L", Cellulose acetate, Cellulose acetate phthalate or Hydroxypropylmethyl Cellulose. These capsules may be used as such, or alternatively, the lyophilised material may be reconstituted prior to administration, e.g. as a suspension. Reconstitution is advantageously effected in buffer at a suitable pH to ensure the viability of the organisms. In order to protect the attenuated bacteria and the vaccine from gastric acidity, a sodium bicarbonate preparation is advantageously administered before each administration of the vaccine. Alternatively, the vaccine may be prepared for parenteral administration, intranasal administration or intramammary administration.

The attenuated bacterium containing the DNA construct or fusion protein of the invention may be used in the prophylactic treatment of a host, particularly a human host but also possibly an animal host. An infection caused by a microorganism, especially a pathogen, may therefore be prevented by administering an effective dose of an attenuated bacterium according to the invention. The bacterium then expresses the fusion protein which is

capable of raising antibody to the micro-organism. The dosage employed will be dependent on various factors including the size and weight of the host, the type of vaccine formulated and the nature of the fusion protein.

An attenuated bacterium according to the present invention may be prepared by transforming an attenuated bacterium with a DNA construct as hereinbefore defined. Any suitable transformation technique may be employed, such as electroporation. In this way, an attenuated bacterium capable of expressing a protein or proteins heterologous to the bacterium may be obtained. A culture of the attenuated bacterium may be grown under aerobic conditions. A sufficient amount of the bacterium is thus prepared for formulation as a vaccine, with minimal expression of the fusion protein occurring.

The DNA construct may be a replicable expression vector comprising the nirB promoter operably linked to a DNA sequence encoding the fusion protein. The nirB promoter may be inserted in an expression vector, which already incorporates a gene encoding one of the heterologous proteins (e.g. the tetanus toxin C fragment), in place of the existing promoter controlling expression of the protein. The gene encoding the other heterologous protein (e.g. an antigenic sequence) may then be inserted. The expression vector should, of course, be compatible with the attenuated bacterium into which the vector is to be inserted.

The expression vector is provided with appropriate

transcriptional and translational control elements including, besides the nirB promoter, a transcriptional termination site and translational start and stop codons. An appropriate ribosome binding site is provided. The vector typically comprises an origin of replication and, if desired, a selectable marker gene such as an antibiotic resistance gene. The vector may be a plasmid.

The invention will now be illustrated but not limited, by reference to the following examples and the accompanying drawings, in which:

Figure 1 is a schematic illustration of the construction of plasmid pTECH1;

Figure 2 illustrates schematically the preparation of the plasmid pTECH1-28 from the starting materials pTECH1 and PUC19-P28;

Figure 3 illustrates schematically the preparation of the plasmid pTECH3-P28 from the starting materials plasmids pTECH1-P28 and pTETnir15;

Figures 4 and 5 are western blots obtained from bacterial cells harbouring the pTECH3-P28 construct; and

Figure 6 illustrates the glutathione affinity purification of TetC fusions as determined by SDS-PAGE and Coomassie Blue Staining.

In accordance with the invention a vector was constructed to allow genetic fusions to the C-terminus of the highly immunogenic C fragment of tetanus toxin, without the use of a heterologous hinge domain. A fusion was constructed, with the gene encoding the protective 28kDa

glutathione *S*-transferase from Schistosoma mansoni. The recombinant vector was transformed into *Salmonella typhimurium* (SL338; *rm*⁺). The resulting chimeric protein was stably expressed in a soluble form in salmonella as assessed by western blotting with fragment C and glutathione *S*-transferase antisera. Furthermore it was found that the P28 component of the fusion retains the capacity to bind glutathione.

The construction of the vector and the properties of the fusion protein expressed therefrom are described in more detail below.

EXAMPLE 1

Preparation of pTECH1

The preparation of pTECH1, a plasmid incorporating the nirB promoter and TetC gene, and a DNA sequence encoding a hinge region and containing restriction endonuclease sites to allow insertion of a gene coding for a second or guest protein, is illustrated in Figure 1. Expression plasmid pTETnir15, the starting material shown in Figure 1, was constructed from pTETtac115 (Makoff *et al*, Nucl. Acids Res. 17 10191-10202, 1989); by replacing the EcoRI-ApaI region (1354bp) containing the lacI gene and tac promoter with the following pair of oligos 1 and 2:

Oligo-1 5'AATTCAGGTAAATTTGATGTACATCAAATGGTACCCCTTGCTGAAT
CGTTAAGGTAGGCGGTAGGGCC-3' (SEQ ID NO: 2)

Oligo-2 3'-GTCCATTTAAACTACATGTAGTTTACCATGGGGAACGACTTA
GCAATTCATCCGCCATC-5' (SEQ ID NO: 3)

The oligonucleotides were synthesised on a Pharmacia Gene Assembler and the resulting plasmids confirmed by sequencing (Makoff et al, Bio/Technology 7, 1043-1046, 1989).

The pTETnir15 plasmid was then used for construction of the pTECH1 plasmid incorporating a polylinker region suitable as a site for insertion of heterologous DNA to direct the expression of fragment C fusion proteins. pTETnir15 is a known pAT153-based plasmid which directs the expression of fragment C. However, there are no naturally occurring convenient restriction sites present at the 3'-end of the TetC gene. Therefore, target sites, preceded by a hinge region, were introduced at the 3'-end of the TetC coding region by means of primers SEQ ID NO: 4 and SEQ ID NO: 5 tailored with "add-on" adapter sequences (Table 1), using the polymerase chain reaction (PCR) [K. Mullis et al, Cold Spring Harbor Sym. Quant. Biol. 51, 263-273 1986]. Accordingly, pTETnir15 was used as a template in a PCR reaction using primers corresponding to regions covering the SacII and BamHI sites. The anti-sense primer in this amplification was tailored with a 38 base 5'-adaptor sequence. The anti-sense primer was designed so that a sequence encoding novel XbaI, SpeI and BamHI sites were incorporated into the PCR product. In addition, DNA sequences encoding additional extra amino acids including proline were incorporated (the hinge regions) and a translation stop codon signal in frame with the fragment C open reading frame.

The PCR product was gel-purified and digested with SacII and BamHI, and cloned into the residual 2.8 kb vector pTETnir15 which had previously been digested by SacII and BamHI. The resulting plasmid purified from transformed colonies and named pTECH 1 is shown in Figure 1. Heterologous sequences such as the sequence encoding the Schistosoma mansoni P28 glutathione S-transferase (P28) were cloned into the XbaI SpeI and BamHI sites in accordance with known methods.

The DNA sequence of the plasmid pTECH1 is shown in the sequence listing as SEQ ID NO: 6.

TABLE 1

DNA SEQUENCES OF OLIGONUCLEOTIDES UTILISED IN THE CONSTRUCTION OF THE TETC-HINGE VECTORS

A). Primer 1. Sense PCR (21mer). (SEQ ID NO: 4)

SacII

5'AAA GAC TCC GCG GGC GAA GTT -3'

TETANUS TOXIN C FRAGMENT SEQ.

B).Primer 2. Anti-Sense PCR Primer (64mer). (SEQ ID NO: 5)

BamHI STOP SpeI XbaI ~~ATGCG TGGGCG~~

5'- CTAT GGA TCC TTA ACT AGT GAT TCT AGA ~~TTT TTT TTT TTT~~
GTC GTT GGT CCA ACC TTC ATC GGT -3'

TETANUS TOXIN C FRAGMENT SEQ. 3'-END

EXAMPLE 2

Construction of pTECH1-P28

A P28 gene expression cassette was produced by PCR

using pUC19-P28 DNA (a kind gift from Dr R Pierce, Pasteur Institute, Lille) as template. Oligonucleotide primers were designed to amplify the full length P28 gene beginning with the start codon and terminating with the stop codon. In addition, the sense and antisense primers were tailored with the restriction sites for XbaI and BamHI respectively. The primers are shown in the sequence listing as SEQ ID NO: 7 and SEQ ID NO: 8.

The product was gel-purified and digested with XbaI and BamHI and then cloned into pTECH1 which had previously been digested with these enzymes and subsequently gel-purified. The DNA sequence of pTECH1 - P28 is shown in sequence listing as SEQ ID NO: 9.

Expression of the TetC-Hinge-P28 fusion protein

Several bacterial strains, namely S. typhimurium strains SL 5338 (A. Brown et al, J.Infect.Dis. 155, 86-92, 1987) and SL3261 and E. coli (TG2) were transformed with pTECH1-P28 by means of electroporation. SL3261 strains harbouring the pTECH1-P28 plasmid have been deposited at the National Collection of Type Cultures, 61 Colindale Avenue, London, NW9 5HT, UK under the accession number NCTC 12833. A strain of SL3261 containing the pTECH1 plasmid has been deposited under accession number NCTC 12831. The identity of recombinants was verified by restriction mapping of the plasmid DNA harboured by the cells. Further expression of the TetC-P28 fusion protein was then evaluated by SDS-PAGE and western blotting of bacterial cells harbouring the construct. It was found that the

fusion protein remains soluble, cross-reacts with antisera to both TetC and P28, and is also of the expected molecular weight, 80kDal, for a full length fusion.

The fusion protein was stably expressed in E.coli (TG2) and S. typhimurium (SL5338,SL3261) as judged by SDS-PAGE and western blotting. Of interest was a band of 50kDal which co-migrates with the TetC-Hinge protein alone and cross-reacts exclusively with the anti-TetC sera is visible in a western blot. As the codon selection in the hinge region has been designed to be suboptimal, the rare codons may cause pauses during translation which may occasionally lead to the premature termination of translation, thus accounting for this band.

Affinity purification of the TetC-P28 fusion

Glutathione is the natural substrate for P28, a glutathione S-transferase. The amino acid residues involved in binding glutathione are thought to be spatially separated in the primary structure of the polypeptide and brought together to form a glutathione binding pocket in the tertiary structure (P. Reinemer *et al.* EMBO, J8, 1997-2005, 1991). In order to gauge whether the P28 component of the fusion has folded correctly to adopt a conformation capable of binding glutathione, its ability to be affinity purified on a glutathione-agarose matrix was tested. The results obtained (not shown) demonstrated that TetC-P28 can indeed bind to the matrix and the binding is reversible, as the fusion can be competitively eluted with free glutathione.

EXAMPLE 3Constructi n of pTECH3-P28

The plasmid pTECH1-P28 directs the expression of the S. mansoni P28 protein as a C-terminal fusion to fragment C from tetanus toxin separated by a heterologous hinge domain. Expression of the fusion protein is under the control of the nirB promoter. The vector pTECH3-P28 was in part constructed from the plasmid pTETnir15 by the polymerase chain reaction (PCR) using the high fidelity thermostable DNA polymerase from Pyrococcus furiosus, which possesses an associated 3'5' exonuclease proofreading activity. The sequence of steps is summarised in Figure 5. In order to generate a TetC-hingeless replacement cassette, the segment of DNA from the unique SacII site within the TetC gene to the final codon was amplified by means of the PCR reaction, using pTETnir15 as template DNA. The primers used in the PCR amplification are shown in the sequence listing as SEQ ID NO: 10 and SEQ ID NO: 11. The antisense primer in this amplification reaction was tailored with an XbaI recognition sequence.

The amplification reaction was performed according to the manufacturer's instructions (Stratagene, La Jolla, CA, USA). The product was gel-purified, digested with SacII and XbaI, and then cloned into the residual pTECH1-P28 vector which had been previously digested with the respective enzymes SacII and XbaI. The resulting vector was designated pTECH3-P28. The DNA sequence of pTECH3-P28 is shown in the s quenc listing as SEQ ID NO: 12.

EXAMPLE 4Transformation of *S. typhimurium* SL5338 (galE r⁻m⁺) with pTECH3-P28, and Analysis of the Transformants

S. typhimurium SL5338 (galE r⁻m⁺) were cultured in either L or YT broth and on L-agar with ampicillin (50 g/ml) if appropriate and were transformed with the pTECH3-P28 plasmid. The transformation protocol was based on the method described by MacLachlan and Sanderson. (MacLachlan PR and Sanderson KE, 1985. Transformation of *Salmonella typhimurium* with plasmid DNA : differences between rough and smooth strains. J. Bacteriology 161, 442-445).

A 1ml overnight culture of *S. typhimurium* SL5338 (r⁻m⁺; Brown A, Hormaeche CE, Demarco de Hormaeche R, Dougan G, Winther M, Maskell D, and Stocker BAD, 1987. J. Infect.Dis. 155, 86-92) was used to inoculate 100 ml of LB broth and shaken at 37°C until the culture reached OD₆₅₀ = 0.2. The cells were harvested at 3000 x g and resuspended in 0.5 volumes of ice-cold 0.1M MgCl₂. The cells were pelleted again and resuspended in 0.5 volumes of ice-cold CaCl₂. This step was repeated once more and the cells resuspended in 1 ml of 0.1M CaCl₂ to which was added 50 µl of TES (50 mM Tris, 10 mM EDTA, 50 mM NaCl, pH 8.0). The cells were incubated on ice for 45 to 90 minutes. To 150µl of cells was added 100ng of plasmid DNA in 1 - 2µl. The mixture was incubated on ice for 30 minutes prior to heat-shock at 42°C for 2 minutes, and immediate reincubation on ice for 1 minute. To the transform d mixture was added 2 ml of LB broth and incubated for 1.5 hours to allow

expression of the ampicillin drug resistance gene, B-lactamase. Following incubation 20 μ l and 200 μ l of cells were spread on to LB agar plates containing 50 μ g/ml of ampicillin. The plates were dried and incubated at 37°C overnight.

The identity of recombinants was verified by restriction mapping of the plasmid DNA and by western blotting with antisera directed against TetC and P28.

SDS-PAGE and Western Blotting

Expression of the TetC fusions was tested by SDS-PAGE and western blotting. S. typhimurium SL5338 (galE $r^{-}m^{+}$) bacterial cells containing the pTECH3-P28 plasmid and growing in mid-log phase, with antibiotic selection, were harvested by centrifugation and the proteins fractionated by 10% SDS-PAGE. The proteins were transferred to a nitrocellulose membrane by electroblotting and reacted with either a polyclonal rabbit antiserum directed against TetC or the full length P28 protein. The blots were then probed with goat anti-rabbit Ig conjugated to horse-radish peroxidase (Dako, High Wycombe, Bucks, UK) and developed with 4-chloro-1-naphthol). The results of the western blotting experiments are shown in Figures 4 and 5; Figure 4 illustrating the results of probing with rabbit anti-TetC polyclonal antiserum and Figure 5 illustrates the results of probing with rabbit anti-P28 polyclonal antiserum. In each case lanes 1, 2 and 3 are independent clones of SL5338 (pTECH3-P28), lanes 4, 5 and 6 are SL5338 (pTECH1-P28) and

lane 7 is SL5338 (pTETnir15). The molecular weight markers are indicated. From the results, it is evident that the fusion protein remains soluble, reacts with antisera to both TetC and P28, and is also of the expected molecular weight, 80 kDal, for a full length fusion (Figure 4). Furthermore the fusion protein appears to be stably expressed.

Glutathione-Agarose Affinity Purification

Glutathione is the natural substrate for P28, a glutathione *S*-transferase. The amino acid residues involved in binding glutathione are thought to be spatially separated in the primary structure of the polypeptide and brought together to form a glutathione binding pocket in the tertiary structure. In order to gauge whether the P28 component of the fusion has folded correctly to adopt a conformation capable of binding glutathione, we tested its ability to be affinity purified on a glutathione agarose matrix.

Bacterial cells containing pTECH3-P28 and expressing the TetC full length P28 gene fusion were grown to log phase, chilled on ice, and harvested by centrifugation at 2500 x g for 15 min at 4C. The cells were resuspended in 1/15th the original volume of ice-cold phosphate buffered saline (PBS) and lysed by sonication in a MSE Soniprep 150 (Gallenkamp, Leicester, UK). The insoluble material was removed by centrifugation and to the supernatant was added 1/6 volume of a 50% slurry of pre-swollen glutathione-agarose beads (Sigma, Poole, Dorset, UK). After mixing

gently at room temperature for 1 hour the beads were collected by centrifugation at 1000 x g for 10 secs. The supernatant was discarded and the beads resuspended in 20 volumes of cold PBS-0.5% Triton X100 and the beads collected again by centrifugation. The washing step was repeated three more times. The fusion protein was eluted by adding 1 volume of SDS-PAGE sample buffer. For comparison purposes, a similar procedure was followed with bacterial cells containing the PTECH1-P28 plasmid from which TetC-hinge-P28 fusion protein is expressed. Extracts from clones containing either plasmid were compared using SDS-PAGE and the results are shown in Figure 6. In Figure 6, lanes 1, 2 and 3 are clones of SL5338 (pTECH1-P28) whereas lanes 4, 5 and 6 are independent clones of SL 5338 (pTECH3-P28).

The results suggest that the TetC-P28 fusion protein can indeed bind to the matrix and the binding is reversible regardless of the absence of a heterologous hinge domain (data not shown). It is possible that a peptide sequence present at the C-terminus of TetC may in fact impart flexibility to this particular region.

SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT:

- (A) NAME: MEDEVA HOLDINGS BV
- (B) STREET: CHURCHILL-LAAN 223
- (C) CITY: AMSTERDAM
- (E) COUNTRY: THE NETHERLANDS
- (F) POSTAL CODE (ZIP): 1078 ED

(ii) TITLE OF INVENTION: VACCINES

(iii) NUMBER OF SEQUENCES: 20

(iv) COMPUTER READABLE FORM:

- (A) MEDIUM TYPE: Floppy disk
- (B) COMPUTER: IBM PC compatible
- (C) OPERATING SYSTEM: PC-DOS/MS-DOS
- (D) SOFTWARE: PatentIn Release #1.0, Version #1.25 (EPO)

(vi) PRIOR APPLICATION DATA:

- (A) APPLICATION NUMBER: PCT/GB93/01617
- (B) FILING DATE: 30-JUL-1993

(vi) PRIOR APPLICATION DATA:

- (A) APPLICATION NUMBER: GB 9401787.8
- (B) FILING DATE: 31-JAN-1994

(2) INFORMATION FOR SEQ ID NO: 1:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 68 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: NO

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Escherichia coli

(ix) FEATURE:

- (A) NAME/KEY: promoter
- (B) LOCATION: 1..61

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 1:

AATTCAGGTA AATTTGATGT ACATCAAATG GTACCCCTTG CTGAATCGTT AAGGTAGGCG 60
GTAGGGCC 68

(2) INFORMATION FOR SEQ ID NO: 2:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 68 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 2:

AATTCAGGTA AATTTGATGT ACATCAAATG GTACCCCTTG CTGAATCGTT AAGGTAGGCG 60
GTAGGGCC 68

(2) INFORMATION FOR SEQ ID NO: 3:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 60 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 3:

GTCCATTTAA ACTACATGTA GTTTACCATG GGGAACTAGT TAGCAATTCC ATCCGCCATC 60

(2) INFORMATION FOR SEQ ID NO: 4:

(i) SEQUENCE CHARACTERISTICS:

24

- (A) LENGTH: 21 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (iii) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 4:

AAAGACTCCG CGGGCGAAGT T

21

(2) INFORMATION FOR SEQ ID NO: 5:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 64 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO
- (iii) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 5:

CTATGGATCC TTAAGTAGTG ATTCTAGAGG GCGGCGGCCC GTCGTTGGTC CAACCTTCAT
CGGT

60

64

(2) INFORMATION FOR SEQ ID NO: 6:

- (i) SEQUENCE CHARACTERISTICS:
 - (A) LENGTH: 3754 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: double
 - (D) TOPOLOGY: circular
- (ii) MOLECULE TYPE: DNA (genomic)
- (iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 6:

TTCAGGTAAA TTTGATGTAC ATCAAATGGT ACCCCTTGCT GAATCGTTAA GGTAGGCGGT	60
AGGGCCCAGA TCTTAATCAT CCACAGGAGA CTTTCTGATG AAAAACCTTG ATTGTTGGGT	120
CGACAACGAA GAAGACATCG ATGTTATCCT GAAAAAGTCT ACCATTCTGA ACTTGGACAT	180
CAACAACGAT ATTATCTCCG ACATCTCTGG TTTCAACTCC TCTGTTATCA CATATCCAGA	240
TGCTCAATTG GTGCCGGGCA TCAACGGCAA AGCTATCCAC CTGGTTAACA ACGAATCTTC	300
TGAAGTTATC GTGCACAAGG CCATGGACAT CGAATACAAC GACATGTTCA ACAACTTCAC	360
CGTTAGCTTC TGGCTGCGCG TTCCGAAAGT TTCTGCTTCC CACCTGGAAC AGTACGGCAC	420
TAACGAGTAC TCCATCATCA GCTCTATGAA GAAACACTCC CTGTCCATCG GCTCTGGTTG	480
GTCTGTTTCC CTGAAGGGTA ACAACCTGAT CTGGACTCTG AAAGACTCCG CGGGCGAAGT	540
TCGTCAGATC ACTTTCCGCG ACCTGCCGGA CAAGTTCAAC GCGTACCTGG CTAACAAATG	600
GGTTTTTCATC ACTATCACTA ACGATCGTCT GTCTTCTGCT AACCTGTACA TCAACGGCGT	660
TCTGATGGGC TCCGCTGAAA TCACTGGTCT GGGCGCTATC CGTGAGGACA ACAACATCAC	720
TCTTAAGCTG GACCGTTGCA ACAACAACAA CCAGTACGTA TCCATCGACA AGTTCCGTAT	780
CTTCTGCAAA GCACTGAACC CGAAAGAGAT CGAAAACTG TATACCAGCT ACCTGTCTAT	840
CACCTTCCTG CGTGACTTCT GGGGTAACCC GCTGCGTTAC GACACCGAAT ATTACCTGAT	900
CCCGGTAGCT TCTAGCTCTA AAGACGTTCA GCTGAAAAAC ATCACTGACT ACATGTACCT	960
GACCAACGCG CCGTCCTACA CTAACGGTAA ACTGAACATC TACTACCGAC GTCTGTACAA	1020
CGGCCTGAAA TTCATCATCA AACGCTACAC TCCGAACAAC GAAATCGATT CTTTCGTTAA	1080
ATCTGGTGAC TTCATCAAAC TGTACGTTTC TTACAACAAC AACGAACACA TCGTTGGTTA	1140
CCCGAAAGAC GGTAAACGCTT TCAACAACCT GGACAGAATT CTGCGTGTTG GTTACAACGC	1200
TCCGGGTATC CCGCTGTACA AAAAAATGGA AGCTGTTAAA CTGCGTGACC TGAAAACCTA	1260
CTCTGTTTCA CTGAAACTGT ACGACGACAA AAACGCTTCT CTGGGTCTGG TTGGTACCCA	1320
CAACGGTCAG ATCGGTAACG ACCCGAACCG TGACATCCTG ATCGCTTCTA ACTGGTACTT	1380
CAACCACCTG AAAGACAAAA TCCTGGGTTG CGACTGGTAC TTCGTTCCGA CCGATGAAGG	1440

TTGGACCAAC	GACGGGCCGG	GGCCCTCTAG	AATCACTAGT	TAAGGATCCG	CTAGCCCGCC	1500
TAATGAGCGG	GCTTTTTTTT	CTCGGGCAGC	GTTGGGTCTT	GGCCACGGGT	GCGCATGATC	1560
GTGCTCCTGT	CGTTGAGGAC	CCGGCTAGGC	TGGCGGGGTT	GCCTTACTGG	TTAGCAGAAT	1620
GAATCACC GA	TACGCGAGCG	AACGTGAAGC	GACTGCTGCT	GCAAAACGTC	TGCGACCTGA	1680
GCAACAACAT	GAATGGTCTT	CGGTTTCCGT	GTTTCGTAAA	GTCTGGAAAC	GCGGAAGTCA	1740
GCGCTCTTCC	GCTTCCTCGC	TCCTGACTC	GCTGCGCTCG	GTCGTTCCGC	TGCGGCGAGC	1800
GGTATCAGCT	CACTCAAAGG	CGGTAATACG	GTTATCCACA	GAATCAGGGG	ATAACGCAGG	1860
AAAGAACATG	TGAGCAAAAG	GCCAGCAAAA	GGCCAGGAAC	CGTAAAAAGG	CCGCGTTGCT	1920
GGCGTTTTTC	CATAGGCTCC	GCCCCCTGA	CGAGCATCAC	AAAAATCGAC	GCTCAAGTCA	1980
GAGGTGGCGA	AACCCGACAG	GACTATAAAG	ATACCAGGCG	TTTCCCCCTG	GAAGCTCCCT	2040
CGTGCGCTCT	CCTGTTCCGA	CCCTGCCGCT	TACCGGATAC	CTGTCCGCCT	TTCTCCCTTC	2100
GGGAAGCGTG	GCGCTTTCTC	AATGCTCACG	CTGTAGGTAT	CTCAGTTCGG	TGTAGGTCGT	2160
TCGCTCCAAG	CTGGGCTGTG	TGCACGAACC	CCCCGTTTCA	CCCGACCGCT	GCGCCTTATC	2220
CGGTAACAT	CGTCTTGAGT	CCAACCCGGT	AAGACACGAC	TTATCGCCAC	TGGCAGCAGC	2280
CACTGGTAAC	AGGATTAGCA	GAGCGAGGTA	TGTAGGCGGT	GCTACAGAGT	TCTTGAAGTG	2340
GTGGCCTAAC	TACGGCTACA	CTAGAAGGAC	AGTATTTGGT	ATCTGCGCTC	TGCTGAAGCC	2400
AGTTACCTTC	GGAAAAAGAG	TTGGTAGCTC	TTGATCCGGC	AAACAAACCA	CCGCTGGTAG	2460
CGGTGGTTTT	TTTGTTTGCA	AGCAGCAGAT	TACGCGCAGA	AAAAAAGGAT	CTCAAGAAGA	2520
TCCTTTGATC	TTTTCTACGG	GGTCTGACGC	TCAGTGGAAC	GAAAACTCAC	GTTAAGGGAT	2580
TTTGGTCATG	AGATTATCAA	AAAGGATCTT	CACCTAGATC	CTTTTAAATT	AAAAATGAAG	2640
TTTTAAATCA	ATCTAAAGTA	TATATGAGTA	AACCTGGTCT	GACAGTTACC	AATGCTTAAT	2700
CAGTGAGGCA	CCTATCTCAG	CGATCTGTCT	ATTTTCGTTCA	TCCATAGTTG	CCTGACTCCC	2760
CGTCGTGTAG	ATAACTACGA	TACGGGAGGG	CTTACCATCT	GGCCCCAGTG	CTGCAATGAT	2820
ACCGCGAGAC	CCACGCTCAC	CGGCTCCAGA	TTTATCAGCA	ATAAACCAGC	CAGCCGGAAG	2880
GGCCGAGCGC	AGAAGTGGTC	CTGCAACTTT	ATCCGCCTCC	ATCCAGTCTA	TTAATTGTTG	2940
CCGGGAAGCT	AGAGTAAGTA	GTTCGCCAGT	TAATAGTTTG	CGCAACGTTG	TTGCCATTGC	3000
TGCAGGCATC	GTGGTGTAC	GCTCGTCGTT	TGGTATGGCT	TCATTGAGCT	CCGTTCCCA	3060

ACGATCAAGG CGAGTTACAT GATCCCCCAT GTTGTGCAAA AAAGCGGTTA GCTCCTTCGG 3120
 TCCTCCGATC GTTGTGAGAA GTAAGTTGGC CGCAGTGTGA TCACTCATGG TTATGGCAGC 3180
 ACTGCATAAT TCTCTTACTG TCATGCCATC CGTAAGATGC TTTTCTGTGA CTGGTGAGTA 3240
 CTCAACCAAG TCATTCTGAG AATAGTGTAT GCGGCGACCG AGTTGCTCTT GCCCGGCGTC 3300
 AACACGGGAT AATACCGCGC CACATAGCAG AACTTTAAAA GTGCTCATCA TTGGAAAACG 3360
 TTCTTCGGGG CGAAAACTCT CAAGGATCTT ACCGCTGTTG AGATCCAGTT CGATGTAACC 3420
 CACTCGTGCA CCCAACTGAT CTTCAGCATC TTTTACTTTC ACCAGCGTTT CTGGGTGAGC 3480
 AAAACAGGA AGGCAAAATG CCGCAAAAAA GGAATAAGG GCGACACGGA AATGTTGAAT 3540
 ACTCATACTC TTCCTTTTTT AATATTATTG AAGCATTTAT CAGGGTTATT GTCTCATGAG 3600
 CGGATACATA TTTGAATGTA TTTAGAAAAA TAAACAAATA GGGGTTCCGC GCACATTTCC 3660
 CCGAAAAGTG CCACCTGACG TCTAAGAAAC CATTATTATC ATGACATTAA CCTATAAAAA 3720
 TAGGCGTATC ACGAGGCCCT TTCGTCTTCA AGAA 3754

(2) INFORMATION FOR SEQ ID NO: 7:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 7:

TAGTCTAGAA TGGCTGGCGA GCATATCAAG

30

(2) INFORMATION FOR SEQ ID NO: 8:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 8:

TTAGGATCCT TAGAAGGGAG TTGCAGGCCT

30

(2) INFORMATION FOR SEQ ID NO: 9:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 4378 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: circular

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 9:

TTCAGGTAAA TTTGATGTAC ATCAAATGGT ACCCCTTGCT GAATCGTTAA GGTAGGCGGT 60

AGGGCCCAGA TCTTAATCAT CCACAGGAGA CTTTCTGATG TET C GENE START CODON AAAAACCTTG ATTGTTGGGT 120

CGACAACGAA GAAGACATCG ATGTTATCCT GAAAAAGTCT ACCATTCTGA ACTTGGACAT 180

CAACAACGAT ATTATCTCCG ACATCTCTGG TTTCAACTCC TCTGTTATCA CATATCCAGA 240

TGCTCAATTG GTGCCGGGCA TCAACGGCAA AGCTATCCAC CTGGTTAACA ACGAATCTTC 300

TGAAGTTATC GTGCACAAGG CCATGGACAT CGAATACAAC GACATGTTCA ACAACTTCAC 360

CGTTAGCTTC TGGCTGCGCG TTCCGAAAGT TTCTGCTTCC CACCTGGAAC AGTACGGCAC 420

TAACGAGTAC TCCATCATCA GCTCTATGAA GAAACACTCC CTGTCCATCG GCTCTGGTTG 480

GTCTGTTTCC CTGAAGGGTA ACAACCTGAT CTGGACTCTG SacII AAAGACTCCG CGGGCGAAGT 540

TCGTCAGATC ACTTTCCGCG ACCTGCCGGA CAAGTTCAAC GCGTACCTGG CTAACAAATG 600

GGTTTTTCATC ACTATCACTA ACGATCGTCT GTCTTCTGCT AACCTGTACA TCAACGGCGT 660

TCTGATGGGC TCCGCTGAAA TCACTGGTCT GGGCGCTATC CGTGAGGACA ACAACATCAC 720

TCTTAAGCTG GACCGTTGCA ACAACAACAA CCAGTACGTA TCCATCGACA AGTTCCGTAT	780
CTTCTGCAAA GCACTGAACC CGAAAGAGAT CGAAAACTG TATACCAGCT ACCTGTCTAT	840
CACCTTCCTG CGTGACTTCT GGGGTAACCC GCTGCGTTAC GACACCGAAT ATTACCTGAT	900
CCCGGTAGCT TCTAGCTCTA AAGACGTTCA GCTGAAAAAC ATCACTGACT ACATGTACCT	960
GACCAACGCG CCGTCTTACA CTAACGGTAA ACTGAACATC TACTACCGAC GTCTGTACAA	1020
CGGCCTGAAA TTCATCATCA AACGCTACAC TCCGAACAAC GAAATCGATT CTTTCGTAA	1080
ATCTGGTGAC TTCATCAAAC TGTACGTTTC TTACAACAAC AACGAACACA TCGTTGGTTA	1140
CCCGAAAGAC GGTAACGCTT TCAACAACCT GGACAGAATT CTGCGTGTTG GTTACAACGC	1200
TCCGGGTATC CCGCTGTACA AAAAAATGGA AGCTGTTAAA CTGCGTGACC TGAAAACCTA	1260
CTCTGTTTCTAG CTGAAACTGT ACGACGACAA AAACGCTTCT CTGGGTCTGG TTGGTACCCA	1320
CAACGGTCAG ATCGGTAACG ACCCGAACCG TGACATCCTG ATCGCTTCTA ACTGGTACTT	1380
CAACCACCTG AAAGACAAAA TCCTGGGTTG CGACTGGTAC TTCGTTCCGA CCGATGAAGG	1440
<div style="display: flex; justify-content: space-between; margin-bottom: 5px;"> HINGE DOMAIN XbaI S.Mansoni P28 GENE START </div> TTGGACCAAC GACGGGCCCG <u>GGCCCTCTAG</u> <u>AATGGCTGGC</u> GAGCATATCA AGGTTATCTA	1500
TTTTGACGGA CGCGGACGTG CTGAATCGAT TCGGATGACT CTTGTGGCAG CTGGTGTAGA	1560
CTACGAAGAT GAGAGAATTA GTTTCCAAGA TTGGCCAAAA ATCAAACCAA CTATTCCAGA	1620
CGGACGATTG CCTGCAGTGA AAGTCACTGA TGATCATGGG CACGTGAAAT GGATGTTAGA	1680
GAGTTTGGCT ATTGCACGGT ATATGGCGAA GAAACATCAT ATGATGGGTG AAACAGACGA	1740
GGAATACTAT AGTGTTGAAA AGTTGATTGG TCATGCTGAA GATGTAGAAC ATGAATATCA	1800
CAAACTTTG ATGAAGCCAC AAGAAGAGAA AGAGAAGATA ACCAAAGAGA TATTGAACGG	1860
CAAAGTTCCA GTTCTTCTCA ATATGATCTG CGAATCTCTG AAAGGGTCGA CAGGAAAGCT	1920
GGCTGTTGGG GACAAAGTAA CTCTAGCTGA TTTAGTCTCG ATTGCTGTCA TTGATCATGT	1980
GACTGATCTG GATAAAGGAT TTCTAACTGG CAAGTATCCT GAGATCCATA AACATCGAGA	2040
AAATCTGTTA GCCAGTTCAC CGCGTTTGGC GAAATATTTA TCGAACAGGC CTGCAACTCC	2100
<div style="display: flex; justify-content: space-between; margin-bottom: 5px;"> STOP BamHI </div> CTTCTAAGGA TCCGCTAGCC CGCCTAATGA GCGGGCTTTT TTTTCTCGGG CAGCGTTGGG	2160
TCCTGGCCAC GGGTGCGCAT GATCGTGCTC CTGTCGTTGA GGACCCGGCT AGGCTGGCGG	2220
GGTTGCCTTA CTGGTTAGCA GAATGAATCA CCGATACGCG AGCGAACGTG AAGCGACTGC	2280

TGCTGCAAAA	CGTCTGCGAC	CTGAGCAACA	ACATGAATGG	TCTTCGGTTT	CCGTGTTTCG	2340
TAAAGTCTGG	AAACGCGGAA	GTCAGCGCTC	TTCCGCTTCC	TCGCTCACTG	ACTCGCTGCG	2400
CTCGGTTCGTT	CGGCTGCGGC	GAGCGGTATC	AGCTCACTCA	AAGGCGGTAA	TACGGTTATC	2460
CACAGAATCA	GGGGATAACG	CAGGAAAGAA	CATGTGAGCA	AAAGGCCAGC	AAAAGGCCAG	2520
GAACCGTAAA	AAGGCCGCGT	TGCTGGCGTT	TTTCCATAGG	CTCCGCCCCC	CTGACGAGCA	2580
TCACAAAAAT	CGACGCTCAA	GTCAGAGGTG	GCGAAACCCG	ACAGGACTAT	AAAGATACCA	2640
GGCGTTTCCC	CCTGGAAGCT	CCCTCGTGCG	CTCTCCTGTT	CCGACCCCTG	CGCTTACCGG	2700
ATACCTGTCC	GCCTTTCTCC	CTTCGGGAAG	CGTGGCGCTT	TCTCAATGCT	CACGCTGTAG	2760
GTATCTCAGT	TCGGTGTAGG	TCGTTGCTC	CAAGCTGGGC	TGTGTGCACG	AACCCCCCGT	2820
TCAGCCCGAC	CGCTGCGCCT	TATCCGGTAA	CTATCGTCTT	GAGTCCAACC	CGGTAAGACA	2880
CGACTTATCG	CCACTGGCAG	CAGCCACTGG	TAACAGGATT	AGCAGAGCGA	GGTATGTAGG	2940
CGGTGCTACA	GAGTTCTTGA	AGTGGTGGCC	TAACACGGC	TACACTAGAA	GGACAGTATT	3000
TGGTATCTGC	GCTCTGCTGA	AGCCAGTTAC	CTTCGGAAAA	AGAGTTGGTA	GCTCTTGATC	3060
CGGCAAAACAA	ACCACCGCTG	GTAGCGGTGG	TTTTTTTGTT	TGCAAGCAGC	AGATTACGCG	3120
CAGAAAAAAA	GGATCTCAAG	AAGATCCTTT	GATCTTTTCT	ACGGGGTCTG	ACGCTCAGTG	3180
GAACGAAAC	TCACGTTAAG	GGATTTTGGT	CATGAGATTA	TCAAAAAGGA	TCTTCACCTA	3240
GATCCTTTTA	AATTAATAAT	GAAGTTTTAA	ATCAATCTAA	AGTATATATG	AGTAAACTTG	3300
GTCTGACAGT	TACCAATGCT	TAATCAGTGA	GGCACCTATC	TCAGCGATCT	GTCTATTTTCG	3360
TTCATCCATA	GTTGCCTGAC	TCCCCGTCGT	GTAGATAACT	ACGATACGGG	AGGGCTTACC	3420
ATCTGGCCCC	AGTGCTGCAA	TGATACCGCG	AGACCCACGC	TCACCGGCTC	CAGATTTATC	3480
AGCAATAAAC	CAGCCAGCCG	GAAGGGCCGA	GCGCAGAAGT	GGTCCTGCAA	CTTTATCCGC	3540
CTCCATCCAG	TCTATTAATT	GTTGCCGGGA	AGCTAGAGTA	AGTAGTTCGC	CAGTTAATAG	3600
TTTGCGCAAC	GTTGTTGCCA	TTGCTGCAGG	CATCGTGGTG	TCACGCTCGT	CGTTTGGTAT	3660
GGCTTCATTC	AGCTCCGGTT	CCCAACGATC	AAGGCGAGTT	ACATGATCCC	CCATGTTGTG	3720
CAAAAAGCG	GTTAGCTCCT	TCGGTCCTCC	GATCGTTGTC	AGAAGTAAGT	TGGCCGCAGT	3780
GTTATCACTC	ATGGTTATGG	CAGCACTGCA	TAATTCTCTT	ACTGTCATGC	CATCCGTAAG	3840
ATGCTTTTCT	GTGACTGGTG	AGTACTCAAC	CAAGTCATTC	TGAGAATAGT	GTATGCGGCG	3900

ACCGAGTTGC TCTTGCCCGG CGTCAACACG GGATAATACC GCGCCACATA GCAGAACTTT	3960
AAAAGTGCTC ATCATTGGAA AACGTTCTTC GGGGCGAAAA CTCTCAAGGA TCTTACCGCT	4020
GTTGAGATCC AGTTCGATGT AACCCACTCG TGCACCCAAC TGATCTTCAG CATCTTTTAC	4080
TTTCACCAGC GTTTCTGGGT GAGCAAAAAC AGGAAGGCAA AATGCCGCAA AAAAGGGAAT	4140
AAGGGCGACA CGGAAATGTT GAATACTCAT ACTCTTCCTT TTTCAATATT ATTGAAGCAT	4200
TTATCAGGGT TATTGTCTCA TGAGCGGATA CATATTTGAA TGTATTTAGA AAAATAAACA	4260
AATAGGGGTT CCGCGCACAT TTCCCCGAAA AGTGCCACCT GACGTCTAAG AAACCATTAT	4320
TATCATGACA TTAACCTATA AAAATAGGCG TATCACGAGG CCCTTTCGTC TTCAAGAA	4378

(2) INFORMATION FOR SEQ ID NO: 10:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 21 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 10:

AAAGACTCCG CGGGCGAAGT T

(2) INFORMATION FOR SEQ ID NO: 11:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 30 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: YES

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 11:

TTATCTAGAG TCGTTGGTCC AACCTTCATC

(2) INFORMATION FOR SEQ ID NO: 12:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 4366 base pairs

(B) TYPE: nucleic acid

(C) STRANDEDNESS: double

(D) TOPOLOGY: circular

(ii) MOLECULE TYPE: DNA (genomic)

(iii) HYPOTHETICAL: NO

(iii) ANTI-SENSE: NO

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 12:

TTCAGGTAAA TTTGATGTAC ATCAAATGGT ACCCCTTGCT GAATCGTTAA GGTAGGCGGT	60
AGGGCCCAGA TCTTAATCAT CCACAGGAGA CTTTCTGATG <u>AAAAACCTTG ATTGTTGGGT</u>	120
CGACAACGAA GAAGACATCG ATGTTATCCT GAAAAAGTCT ACCATTCTGA ACTTGACAT	180
CAACAACGAT ATTATCTCCG ACATCTCTGG TTTCAACTCC TCTGTTATCA CATATCCAGA	240
TGCTCAATTG GTGCCGGGCA TCAACGGCAA AGCTATCCAC CTGGTTAACA ACGAATCTTC	300
TGAAGTTATC GTGCACAAGG CCATGGACAT CGAATACAAC GACATGTTCA ACAACTTCAC	360
CGTTAGCTTC TGGCTGCGCG TTCCGAAAGT TTCTGCTTCC CACCTGGAAC AGTACGGCAC	420
TAACGAGTAC TCCATCATCA GCTCTATGAA GAAACACTCC CTGTCCATCG GCTCTGGTTG	480
GTCTGTTTCC CTGAAGGGTA ACAACCTGAT CTGGACTCTG AAAGACTCCG CGGGCGAAGT	540
TCGTCAGATC ACTTTCCGCG ACCTGCCGGA CAAGTTCAAC GCGTACCTGG CTAACAAATG	600
GGTTTTCATC ACTATCACTA ACGATCGTCT GTCTTCTGCT AACCTGTACA TCAACGGCGT	660
TCTGATGGGC TCCGCTGAAA TCACTGGTCT GGGCGCTATC CGTGAGGACA ACAACATCAC	720
TCTTAAGCTG GACCGTTGCA ACAACAACAA CCAGTACGTA TCCATCGACA AGTTCCGTAT	780
CTTCTGCAAA GCACTGAACC CGAAAGAGAT CGAAAACTG TATACCAGCT ACCTGTCTAT	840

CACCTTCCTG	CGTGACTTCT	GGGGTAACCC	GCTGCGTTAC	GACACCGAAT	ATTACCTGAT	900
CCCGGTAGCT	TCTAGCTCTA	AAGACGTTCA	GCTGAAAAAC	ATCACTGACT	ACATGTACCT	960
GACCAACGCG	CCGTCCTACA	CTAACGGTAA	ACTGAACATC	TACTACCGAC	GTCTGTACAA	1020
CGGCCTGAAA	TTCATCATCA	AACGCTACAC	TCCGAACAAC	GAAATCGATT	CTTTCGTTAA	1080
ATCTGGTGAC	TTCATCAAAC	TGTACGTTTC	TTACAACAAC	AACGAACACA	TCGTTGGTTA	1140
CCCgAAAGAC	GGTAACGCTT	TCAACAACCT	GGACAGAATT	CTGCGTGTTG	GTTACAACGC	1200
TCCGGGTATC	CCGCTGTACA	AAAAAATGGA	AGCTGTTAAA	CTGCGTGACC	TGAAAACCTA	1260
CTCTGTTTCA	G	CTGAAACTGT	ACGACGACAA	AAACGCTTCT	CTGGGTCTGG	1320
CAACGGTCAG	ATCGGTAAAC	ACCCGAACCG	TGACATCCTG	ATCGCTTCTA	ACTGGTACTT	1380
CAACCACCTG	AAAGACAAAA	TCCTGGGTTG	CGACTGGTAC	TTCGTTCCGA	CCGATGAAGG	1440
XbaI S.Mansoni P28 GENE START						
TTGGACCAAC	GACTCTAGAA	TGGCTGGCGA	GCATATCAAG	GTTATCTATT	TTGACGGACG	1500
CGGACGTGCT	GAATCGATT	GGATGACTCT	TGTGGCAGCT	GGTGTAGACT	ACGAAGATGA	1560
GAGAATTAGT	TTCCAAGATT	GGCCAAAAAT	CAAACCAACT	ATTCCAGACG	GACGATTGCC	1620
TGCAGTGAAA	GTCAGTGATG	ATCATGGGCA	CGTGAAATGG	ATGTTAGAGA	GTTTGGCTAT	1680
TGCACGGTAT	ATGGCGAAGA	AACATCATAT	GATGGGTGAA	ACAGACGAGG	AATACTATAG	1740
TGTTGAAAAG	TTGATTGGTC	ATGCTGAAGA	TGTAGAACAT	GAATATCACA	AAACTTTGAT	1800
GAAGCCACAA	GAAGAGAAAG	AGAAGATAAC	CAAAGAGATA	TTGAACGGCA	AAGTTCAGT	1860
TCTTCTCAAT	ATGATCTGCG	AATCTCTGAA	AGGGTCGACA	GGAAAGCTGG	CTGTTGGGGA	1920
CAAAGTAACT	CTAGCTGATT	TAGTCCTGAT	TGCTGTCATT	GATCATGTGA	CTGATCTGGA	1980
TAAAGGATTT	CTAACTGGCA	AGTATCCTGA	GATCCATAAA	CATCGAGAAA	ATCTGTTAGC	2040
CAGTTCACCG	CGTTTGGCGA	AATATTTATC	GAACAGGCCT	GCAACTCCCT	STOP BamHI TCTAAGGATC	2100
CGCTAGCCCC	CCTAATGAGC	GGGCTTTTTT	TTCTCGGGCA	GCGTTGGGTC	CTGGCCACGG	2160
GTGCGCATGA	TCGTGCTCCT	GTCGTTGAGG	ACCCGGCTAG	GCTGGCGGGG	TTGCCTTACT	2220
GGTTAGCAGA	ATGAATCACC	GATACGCGAG	CGAACGTGAA	GCGACTGCTG	CTGCAAAACG	2280
TCTGCGACCT	GAGCAACAAC	ATGAATGGTC	TTCGGTTTCC	GTGTTTCGTA	AAGTCTGGAA	2340
ACGCGGAAGT	CAGCGCTCTT	CCGCTTCCTC	GCTCACTGAC	TCGCTGCGCT	CGGTCGTTCC	2400

GCTGCGGCGA	GCGGTATCAG	CTCACTCAAA	GGCGGTAATA	CGGTTATCCA	CAGAATCAGG	2460
GGATAACGCA	GGAAAGAACA	TGTGAGCAAA	AGGCCAGCAA	AAGGCCAGGA	ACCGTAAAAA	2520
GGCCGCGTTG	CTGGCGTTTT	TCCATAGGCT	CCGCCCCCCT	GACGAGCATC	ACAAAAATCG	2580
ACGCTCAAGT	CAGAGGTGGC	GAAACCCGAC	AGGACTATAA	AGATACCAGG	CGTTTCCCCC	2640
TGGAAGCTCC	CTCGTGCGCT	CTCCTGTTCC	GACCCTGCCG	CTTACCGGAT	ACCTGTCCGC	2700
CTTTCTCCCT	TCGGGAAGCG	TGGCGCTTTC	TCAATGCTCA	CGCTGTAGGT	ATCTCAGTTC	2760
GGTGTAGGTC	GTTTCGCTCCA	AGCTGGGCTG	TGTGCACGAA	CCCCCGTTC	AGCCCGACCG	2820
CTGCGCCTTA	TCCGGTAACT	ATCGTCTTGA	GTCCAACCCG	GTAAGACACG	ACTTATCGCC	2880
ACTGGCAGCA	GCCACTGGTA	ACAGGATTAG	CAGAGCGAGG	TATGTAGGCG	GTGCTACAGA	2940
GTTCTTGAAG	TGGTGGCCTA	ACTACGGCTA	CACTAGAAGG	ACAGTATTTG	GSTATCTGCGC	3000
TCTGCTGAAG	CCAGTTACCT	TCGGAAAAAG	AGTTGGTAGC	TCTTGATCCG	GCAAACAAAC	3060
CACCGCTGGT	AGCGGTGGTT	TTTTTGTTTG	CAAGCAGCAG	ATTACGCGCA	GAAAAAAAGG	3120
ATCTCAAGAA	GATCCTTTGA	TCTTTTCTAC	GGGGTCTGAC	GCTCAGTGGA	ACGAAAACTC	3180
ACGTTAAGGG	ATTTTGGTCA	TGAGATTATC	AAAAAGGATC	TTCACCTAGA	TCCTTTTAAA	3240
TTAAAAATGA	AGTTTTAAAT	CAATCTAAAG	TATATATGAG	TAAACTTGGT	CTGACAGTTA	3300
CCAATGCTTA	ATCAGTGAGG	CACCTATCTC	AGCGATCTGT	CTATTTTCGT	CATCCATAGT	3360
TGCCTGACTC	CCCGTCGTGT	AGATAACTAC	GATACGGGAG	GGCTTACCAT	CTGGCCCCAG	3420
TGCTGCAATG	ATACCGCGAG	ACCCACGCTC	ACCGGCTCCA	GATTTATCAG	CAATAAACCA	3480
GCCAGCCGGA	AGGGCCGAGC	GCAGAAGTGG	TCCTGCAACT	TTATCCGCCT	CCATCCAGTC	3540
TATTAATTGT	TGCCGGGAAG	CTAGAGTAAG	TAGTTCGCCA	GTTAATAGTT	TGCGCAACGT	3600
TGTTGCCATT	GCTGCAGGCA	TCGTGGTGTC	ACGCTCGTCG	TTTGGTATGG	CTTCATTGAG	3660
CTCCGGTTCC	CAACGATCAA	GGCGAGTTAC	ATGATCCCCC	ATGTTGTGCA	AAAAAGCGGT	3720
TAGCTCCTTC	GGTCCTCCGA	TCGTTGTCAG	AAGTAAGTTG	GCCGCAGTGT	TATCACTCAT	3780
GGTTATGGCA	GCACTGCATA	ATTCTCTTAC	TGTCATGCCA	TCCGTAAGAT	GCTTTTCTGT	3840
GACTGGTGAG	TACTCAACCA	AGTCATTCTG	AGAATAGTGT	ATGCGGCGAC	CGAGTTGCTC	3900
TTGCCCCGGC	TCAACACGGG	ATAATACCGC	GCCACATAGC	AGAACTTTAA	AAGTGCTCAT	3960
CATTGGAAAA	CGTTCCTTCG	GGCGAAAACT	CTCAAGGATC	TTACCGCTGT	TGAGATCCAG	4020

TTCGATGTAA CCCACTCGTG CACCCAACCTG ATCTTCAGCA TCTTTTACTT TCACCAGCGT	4080
TTCTGGGTGA GCAAAAACAG GAAGGCAAAA TGCCGCAAAA AAGGGAATAA GGGCGACACG	4140
GAAATGTTGA ATACTCATAC TCTTCCTTTT TCAATATTAT TGAAGCATT ATCAGGGTTA	4200
TTGTCTCATG AGCGGATACA TATTTGAATG TATTTAGAAA AATAAACAAA TAGGGGTTC	4260
GCGCACATTT CCCCAGAAAAG TGCCACCTGA CGTCTAAGAA ACCATTATTA TCATGACATT	4220
AACCTATAAA AATAGGCGTA TCACGAGGCC CTTTCGTCTT CAAGAA	4366

CLAIMS

1. A DNA construct comprising a DNA sequence encoding a fusion protein of the formula TetC-(Z)_a-Het, wherein TetC is the C fragment of tetanus toxin, or a protein comprising the epitopes thereof; Het is a heterologous protein, Z is an amino acid, and a is zero or a positive integer, provided that (Z)_a does not include the sequence Gly-Pro.
2. A DNA construct according to Claim 1 wherein (Z)_a is a chain of 0 to 15 amino acids.
3. A DNA construct according to Claim 2 wherein (Z)_a is a chain of less than 4 amino acids.
4. A DNA construct according to Claim 3 wherein (Z)_a is a chain of two or three amino acids, the DNA sequence for which defines a restriction endonuclease cleavage site.
5. A DNA construct according to Claim 2 wherein a is zero.
6. A DNA construct according to Claim 2 in which (Z)_a is free from glycine and/or proline.
7. A DNA construct according to any one of the preceding

Claims wherein the heterologous protein Het is an antigenic sequence derived from a virus, bacterium, fungus, yeast or parasite.

8. A DNA construct according to Claim 7 wherein the heterologous protein Het is the Schistosoma mansoni P28 glutathione S-transferase antigen.
9. A replicable expression vector, for example suitable for use in bacteria, containing a DNA construct as defined in any one of Claims 1 to 8.
10. A host, for example, a bacterium, having integrated into the chromosomal DNA thereof a DNA construct as defined in any one of Claims 1 to 8.
11. A fusion protein as defined in any one of Claims 1 to 8.
12. A process for the preparation of a bacterium (preferably an attenuated bacterium), which process comprises transforming a bacterium with a DNA construct as defined in any one of Claims 1 to 8.
13. A vaccine composition comprising a fusion protein, or an attenuated bacterium expressing said fusion protein, the fusion protein being as defined in any one of Claims 1 to 8; and a pharmaceutically

acceptable carrier.

14. A method of immunising a patient, e.g. a human patient, which comprises administering to the patient an effective immunising amount of a vaccine composition as defined in Claim 13.

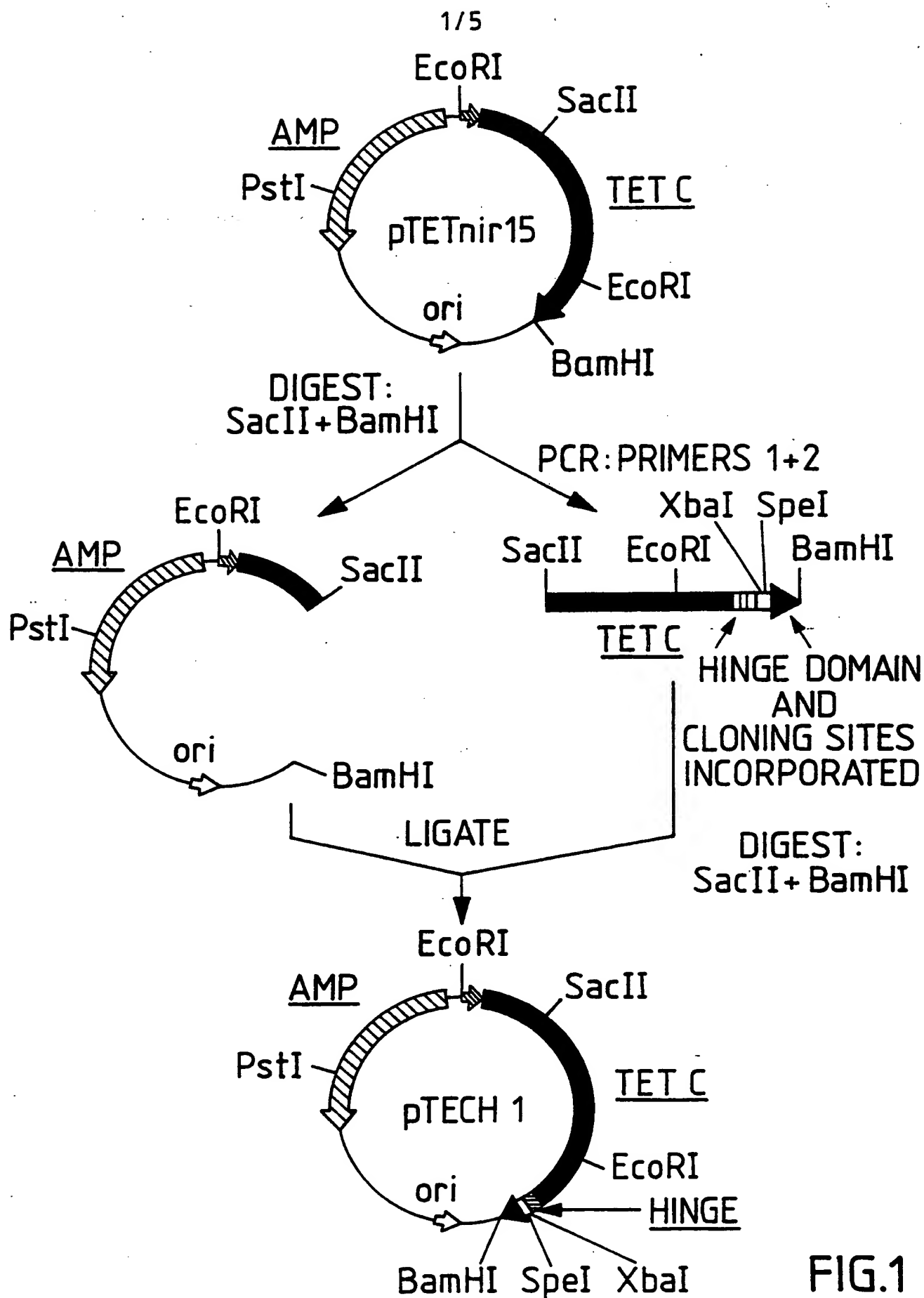


FIG.1

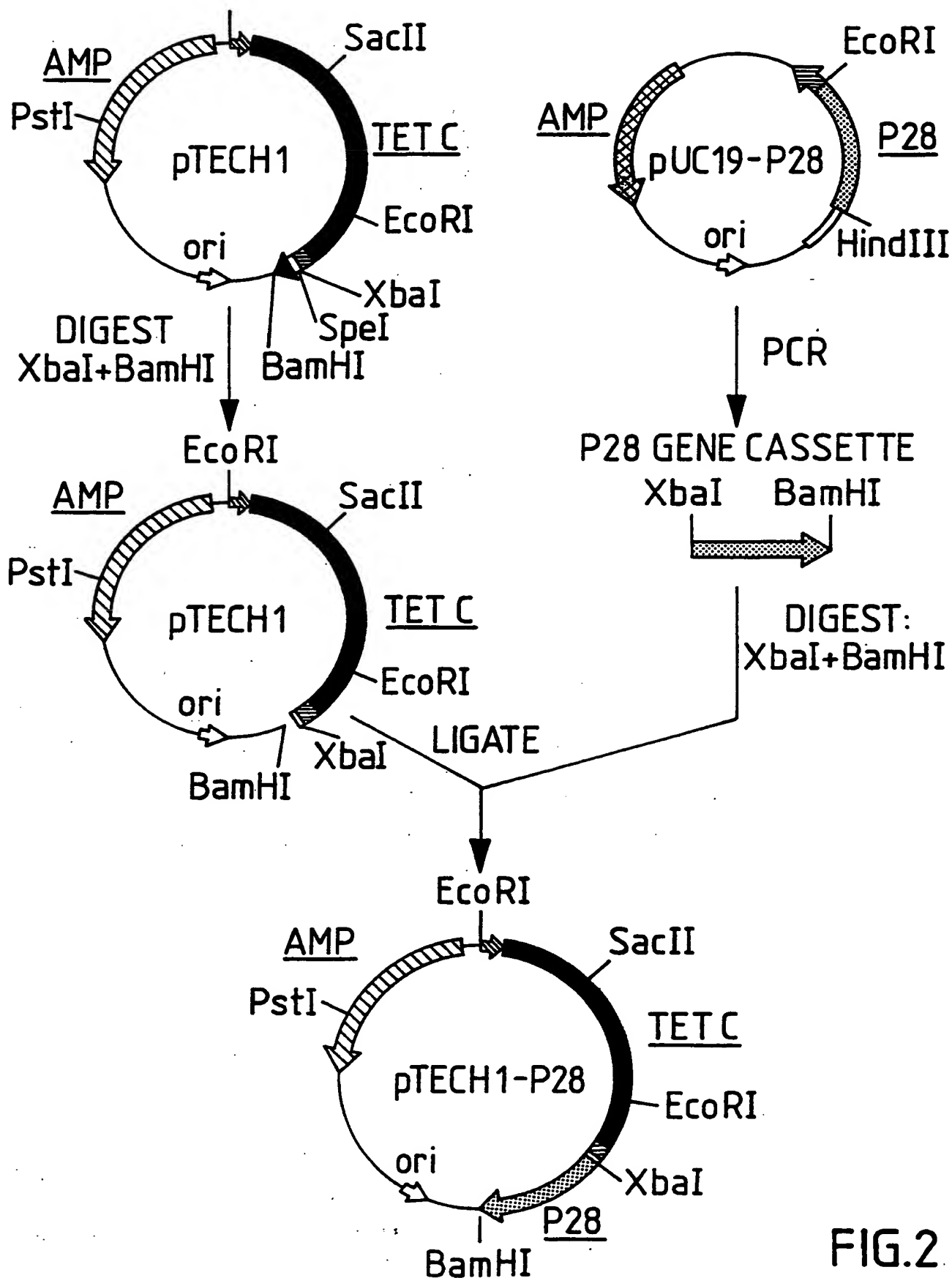


FIG.2

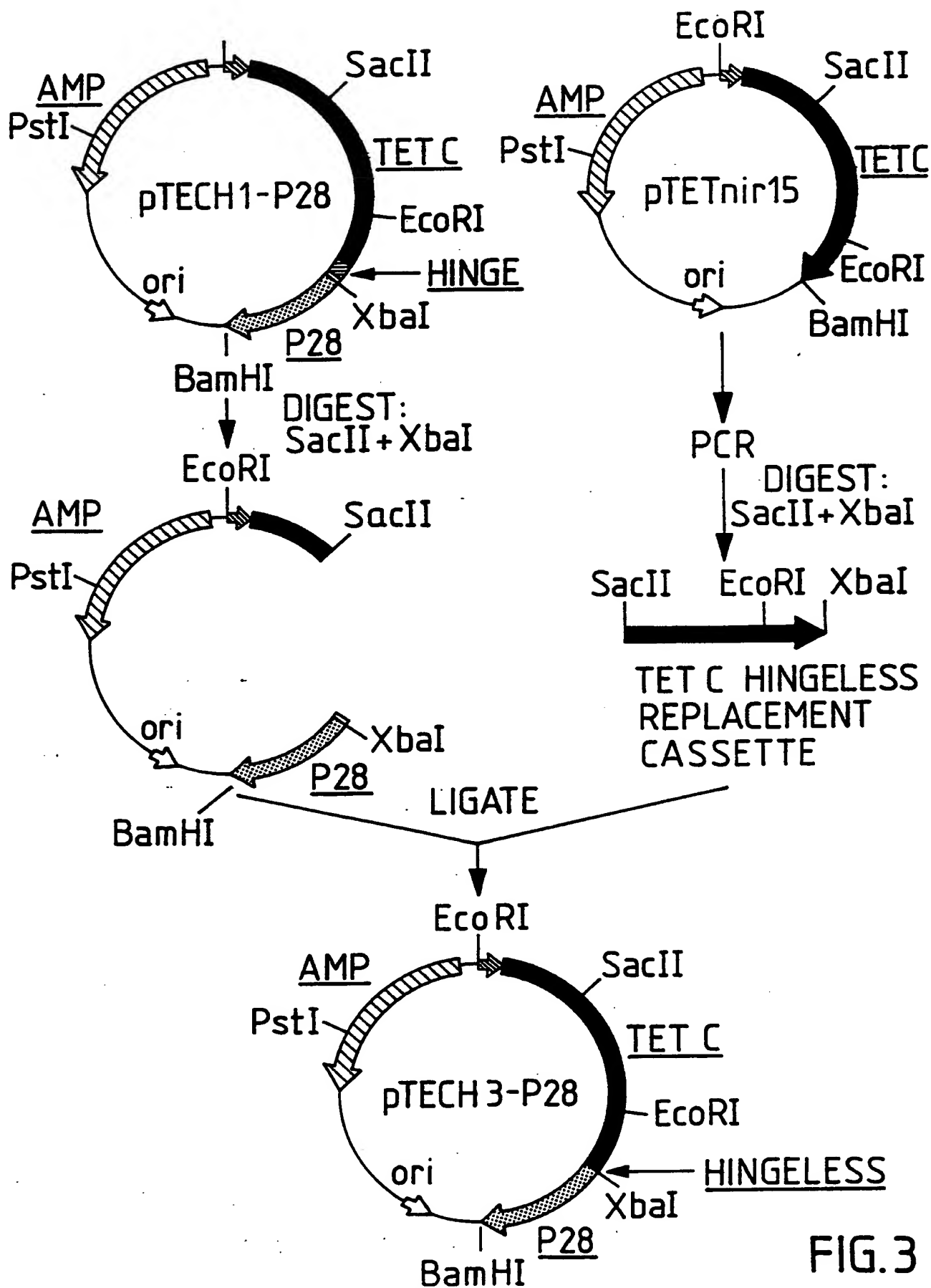


FIG.3

4/5

A

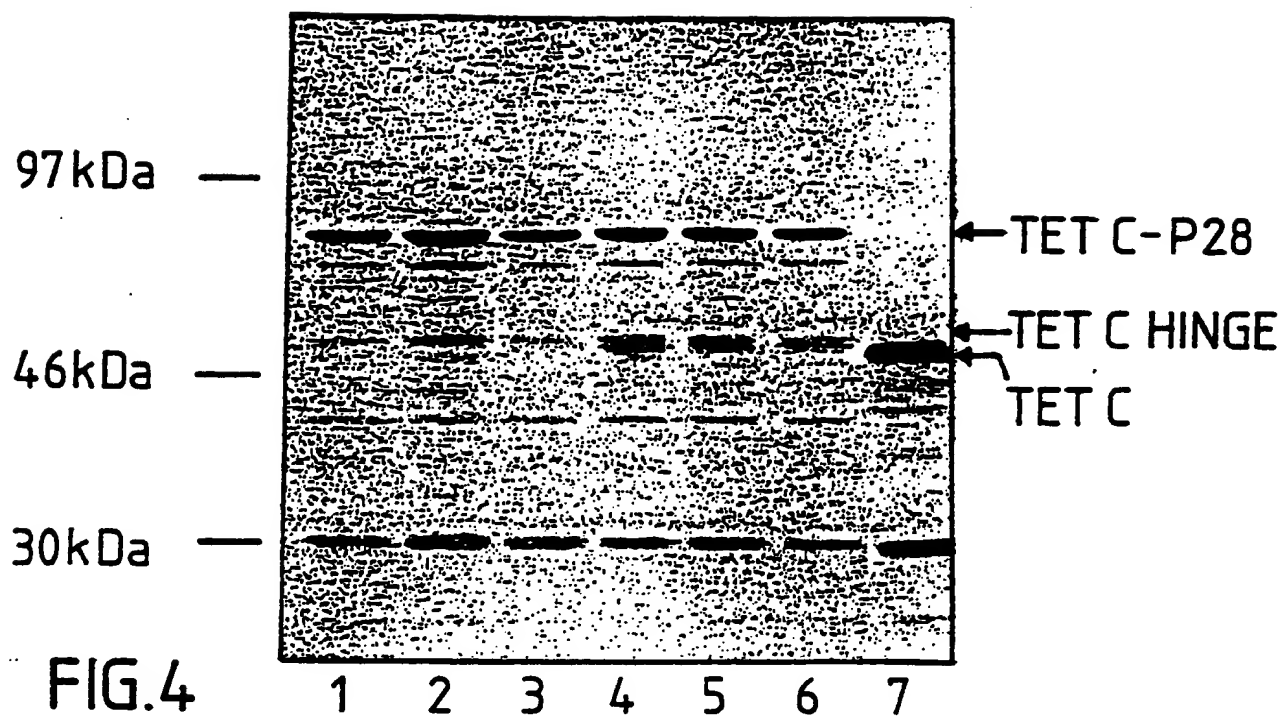


FIG.4

B

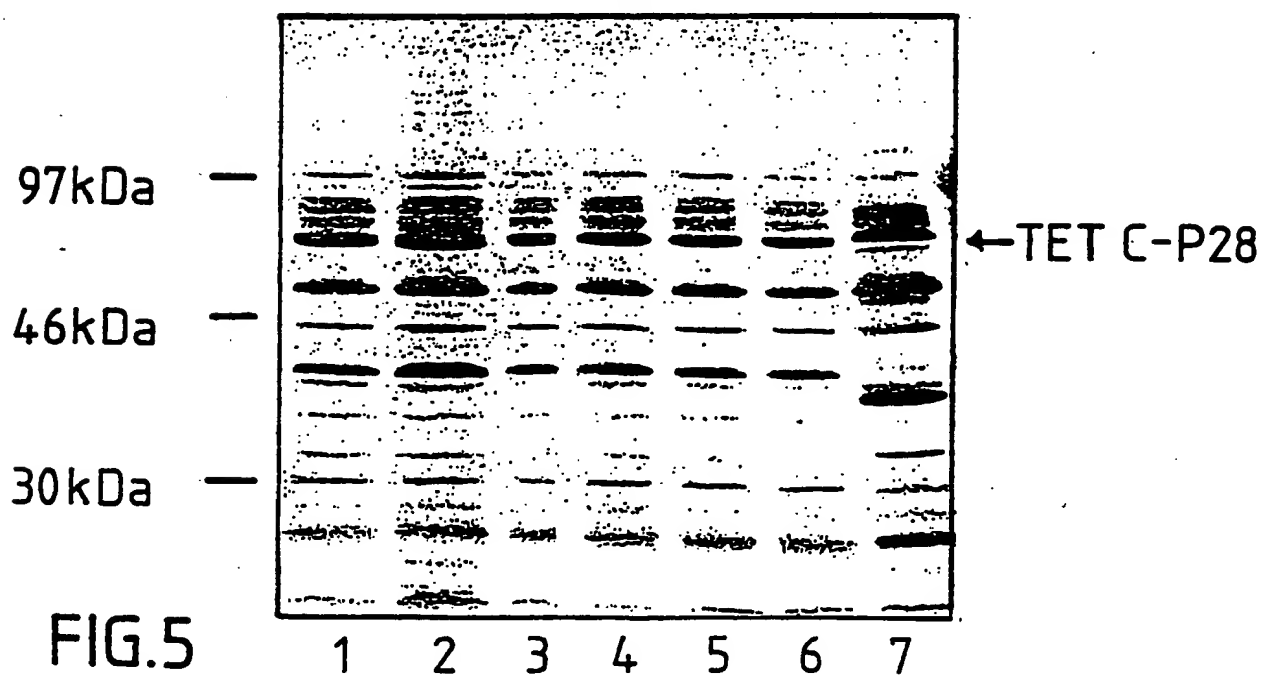


FIG.5

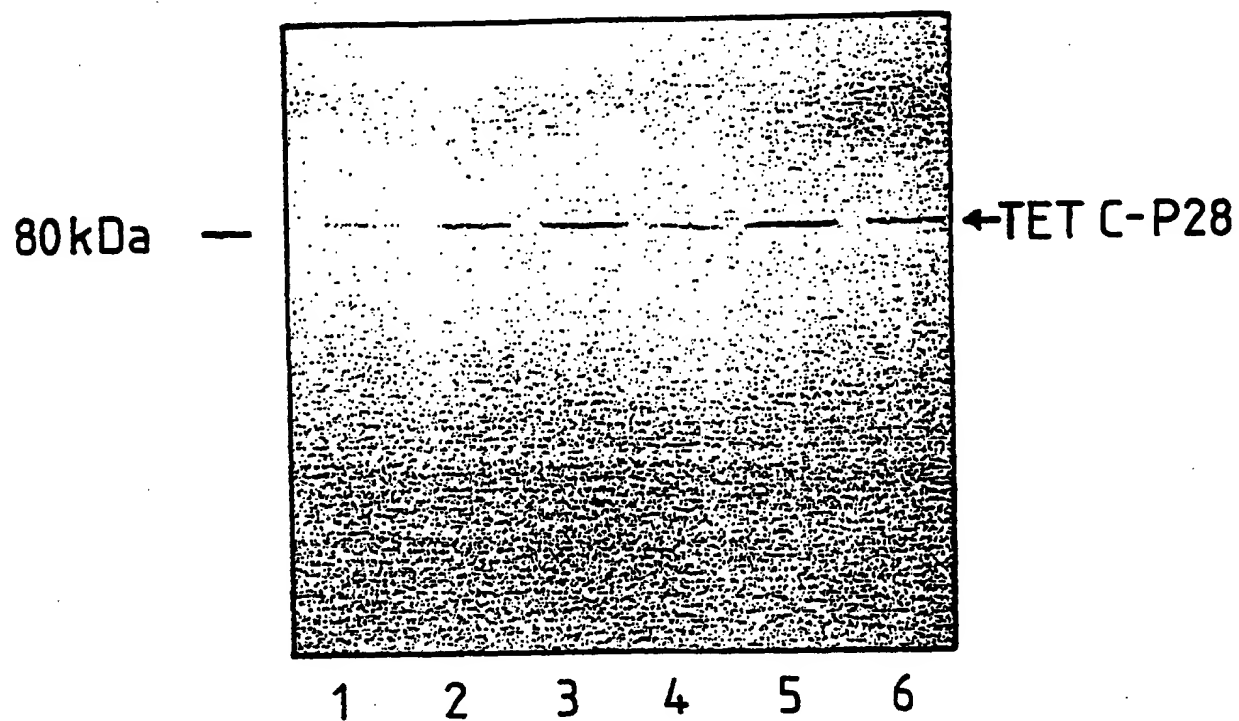


FIG.6